

## MICROMECHANICAL SENSOR

The present invention relates to a micromechanical sensor and a method for manufacturing same.

Micromechanical sensors having a diaphragm are used as  
5 radiation detectors, for example, for measuring infrared radiation in gas sensors or as pressure sensors. The micromechanical diaphragms are generally produced here by etching a cavern from the back side of the machined wafer down to a dielectric layer by using potassium hydroxide (KOH) or  
10 tetramethylammonium hydroxide (TMAH). Several sensors are formed here in one wafer and then separated by cutting the wafer.

More recent approaches begin with etching a cavern beneath the  
15 dielectric layer from the front side of the wafer. To do so, the layer is perforated to allow the etching medium such as chlorine trifluoride ( $\text{ClF}_3$ ) to have access to the substrate material.

20 However, the etching front of the cavern is not smooth but instead has peaks due to the undercutting, which begins at the perforation. The diaphragm is put under tensile stress during the etching process to prevent bulging. The tension increases greatly at peaks in the etching front, which may result in  
25 cracks in the diaphragm. The development of local stress peaks during the etching process is hardly subject to regulation in particular because of the technically induced fluctuations. Therefore, damage may occur during manufacture, and a substantial portion of the sensors thus manufactured may be  
30 defective.

The micromechanical sensor according to the present invention and the method for manufacturing same in particular have the advantage over the related art that the diaphragm restraint no longer depends on the cavern etching process with its technically induced fluctuations.

In addition, the diaphragm restraint may be determined by the layout of the connecting plane of the external oxide layer.

According to the present invention, an oxide layer, preferably a thermal oxide layer, is formed by a LOCOS (local oxidation of silicon) method and is subsequently used for restraint of the diaphragm formed during the etching process. It is therefore possible to produce almost any diaphragm shapes, e.g., circular, but also rectangular, e.g., square.

Due to the LOCOS method used according to the present invention, the diaphragm in the vertical direction is in the area of the thicker external oxide layer, i.e., between the top side and the bottom side of the external oxide layer. Thus there is a symmetrical stress effect acting on the diaphragm during the cavern etching process. This central suspension results in a more uniform introduction of stress into the diaphragm; in addition, relatively flat oxide flanks may be formed advantageously in the suspension area of the diaphragm and may converge at an acute angle in a wedge shape or a triangular shape toward the diaphragm, resulting in an especially uniform introduction of stress in a manner that protects the diaphragm so that cracking is prevented during the etching process - at least for the most part.

Due to its central position in the finished sensor according to the present invention, the diaphragm is also situated in a more protected arrangement than is the case when it is

provided on the top side of the sensor, as is generally the case with traditional etching techniques.

The present invention is based on the surprising finding that LOCOS methods, which have so far been used only for producing integrated circuits, also offer advantages for the additional production of micromechanical diaphragms.

Thus according to the present invention, a reliable and inexpensive manufacturing method which involves a relatively low complexity and has relatively few rejects is made available along with a sensor that has a diaphragm in a protected arrangement, is largely free of damage and may be manufactured inexpensively.

A pressure sensor may be manufactured by subsequently closing the perforation holes in the diaphragm, for example. In addition, an infrared detector for use in a gas sensor may also be produced by applying a thermopile structure and an absorber layer.

The substrate is advantageously made of silicon, using an etching gas such as  $\text{ClF}_3$ , which selectively etches silicon.

The present invention is explained in greater detail below on the basis of the accompanying drawing illustrating one embodiment. The figures illustrate successive steps in a method according to the present invention for manufacturing a micromechanical sensor according to the present invention.

Figure 1 shows a first step in the manufacturing method according to the present invention after the creation of a silicon dioxide layer and a silicon nitride layer on a substrate;

Figure 2 shows the following step after photolithographic structuring;

5 Figure 3 shows a following step after local oxidation;

Figure 4 shows a sensor according to the present invention manufactured by a subsequent step of cavern etching;

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Figure 5 shows an infrared detector as an example of a sensor according to the present invention.

A thin first silicon dioxide ( $\text{SiO}_2$ ) layer 2 is formed by thermal oxidation on a substrate 1 made of silicon or silicon-germanium, and then a silicon nitride ( $\text{Si}_3\text{N}_4$ ) layer 3 is deposited on this silicon dioxide layer subsequently by a CVD (chemical vapor deposition) process according to Figure 1.

20 In the following description, first silicon dioxide layer 2 and silicon nitride layer 3 are removed by an essentially known photolithographic structuring in a laterally external area 4 around an internal diaphragm area 5 according to Figure 2. Internal area 4 may essentially assume any shape, e.g., it  
25 may be circular or rectangular.

According to Figure 3, a LOCOS structure is formed subsequently by local oxidation by creating a thicker second silicon dioxide layer 9 by thermal oxidation in external areas  
30 4. Figure 3 shows the diaphragm layer which forms the subsequent diaphragm and includes layers 2, 3 in simplified form, each having a relatively small thickness. Silicon nitride layer 3 prevents oxidation of substrate 1 in diaphragm area 5, so that second silicon dioxide layer 9 is not formed

here. Second silicon dioxide layer 9 also protrudes partially downward into substrate 1 in comparison with diaphragm area 5. Therefore, a relatively flat LOCOS structure may be formed, the diaphragm layer formed from layers 2 and 3 being situated  
5 in a central area in the vertical direction of the thicker second silicon dioxide layer 9 between its top side 17 and its bottom side 19. A suspension area 10 is formed in second silicon dioxide layer 9 between external area 4 and diaphragm area 5, this suspension area tapering in cross section toward  
10 a connecting point 12 forming an acute angle, e.g., in the form of a wedge, a triangle or a bird's beak.

Optionally following Figure 3, nitride layer 3 may be removed from diaphragm layer 2, 3 by a wet chemical process. The  
15 diaphragm layer may thus be formed by nitride layer 3 and internal oxide layer 2 or by internal oxide layer 2 alone. Essentially the additional deposition of extra layers on internal oxide layer 2 is then also possible to form a suitable diaphragm layer.

20 A cavern 14 is next etched beneath diaphragm area 5. To do so, diaphragm 15 formed by layers 2, 3 is first perforated in a known way by forming perforation holes 16 which allow the access of an etching gas, e.g.,  $\text{ClF}_3$  (chlorine trifluoride),  
25 which selectively etches silicon and protects diaphragm 15 and second silicon dioxide layer 9. Cavern 14 may be designed suitably as a function of the etching parameters, in particular the etching time, etching pressure and etching temperature, and extends according to Figure 4 over suspension  
30 area 10 to approximately beneath second silicon dioxide layer 9. This forms a self-supporting diaphragm 15, which is suspended in acute connecting points 12 on second silicon dioxide layer 9.

Additional layers may be applied subsequently to manufacture a desired sensor. To create an infrared detector 20 for infrared radiation which may be used, for example, in a gas sensor for measuring gas concentrations, first a thermopile structure 18  
5 having conductor areas 21, 22 of different conductive materials, e.g., a metal and polysilicon, which come in contact, e.g., overlap, in a contact area 23, may be subsequently applied to diaphragm 15. An absorber layer 25 may be applied subsequently to form a thermopile sensor 20 in  
10 which the incident infrared radiation results in heating of absorber layers 25, which is measurable as thermal e.m.f. by the thermopile structure of the two conductors.

As an alternative to this, other micromechanical sensors may  
15 also be formed, e.g., a pressure sensor 20 may be formed after sealing perforation holes 16, e.g., by sputtering, according to Figure 4.

Multiple sensors 20 are produced on one wafer and subsequently  
20 separated by cutting.